Reliability of Bioelectrical Impedance Analysis Devices in Assessing Body Composition

Honors Thesis

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By

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Problem Statement

The body composition of both recreational and elite athletes is frequently evaluated in sports nutrition as an objective indicator of training program efficacy. Assessing an athlete's body composition can also be utilized in calculating estimated nutrition requirements, assessing hydration status, and identifying health concerns, such as increased body fatness or poor bone mineral density.

Techniques used to assess body composition can range from basic anthropometrics such as weight, body mass index (BMI), skinfold measurements, and waist circumference, to more complex methods like dual-energy X-ray absorptiometry (iDXA) and bioelectrical impedance analysis (BIA). These complex methods provide a more thorough assessment of body composition, such as the capability of estimating the amount and distribution of fat, lean body mass, and bone mass as with iDXA technology (Duren et al.). While several BIA devices are also capable of providing this data, the complexity of BIA devices varies; some devices measure total body composition while others only provide estimation of body fat percentage.

BIA and iDXA methodologies are used in clinical and laboratory settings for diagnostic and research purposes, as well as in fitness and athletic settings as a performance indicator and training tool for athletes. These two complex methods of body composition assessment vary greatly in price and portability, which is an important determining factor in purchasing and application decisions. An iDXA is far more expensive and less portable than most BIA devices, possibly contributing to the increasing use of BIA. BIA is a popular method of assessing body composition due to its wide availability, portability, and low-cost (Duren et al.). It is also a quicker, more simplistic, and non-invasive method of estimating body composition compared to the iDXA (Jackson et al.). BIA devices have gained popularity due to these advantages.

The advent of newer BIA devices with eight contact points that use multiple frequencies has added to the popularity of BIA technology. The marketing companies of these machines claim they provide highly accurate and reproducible data. There are limited reliability and validity data on the newer BIA devices, and the increasing popularity of BIA devices implies the necessity for assessing their consistency in estimating body composition on multiple encounters within typical uses.

Objective

There is limited research assessing the dependability of BIA devices on more than two occasions. Therefore, the purpose of this study is to ***evaluate the reliability of four selected BIA devices (InBody 770, Tanita Body Composition Analyzer SC-331, Omron HBF-*****306CN*****, and Greater Goods Digital Home Scale) across five serial encounters***. The information obtained from this study could be relevant in settings where BIA is used to estimate and monitor body composition.

Literature Review

BIA Methodology

In general, BIA technology transmits a small, single- or multi-frequency electrical current through an individual’s body via either electrodes or metal contacts. The impedance (resistance) and reactance of the electrical current is measured to estimate body composition

(Moon). The resistance and reactance values originate from fat mass and lean body mass in the body, respectively. Lean tissues, such as muscle, contain a larger amount of water compared to adipose tissue and bone tissues, making muscle a better conductor of electricity. Conversely, fat is an insulator and does not conduct a current well, and thus offers resistance or impedance to the current. Once calculated, impedance is analyzed by a machine equation to produce estimates of total body water (TBW), body fat percentage, and lean body mass (Duren et al.).

Given that water is a great conductor of electricity, it stands to reason that the amount of water in the body can influence the electrical resistance and reactance. Under- and overhydration can lead to erroneous body composition values (Sivapathy et al.). For example, a dehydrated individual may present with a lower body water content which may result in overestimation of fat mass and underestimation of lean body mass. When applying BIA methodology to athletes, the degree of glycogen loading or depletion will influence the water held in the muscle and the liver, and may lead to measurement errors (Shiose et al.). BIA technology relies heavily on assumptions of adequate hydration (Duren et al.), and controlling for hydration status may be important to machine reliability. While it makes sense to control for hydration, individuals rarely consider changes in hydration when using these machines within typical uses.

Brief History of BIA Devices

BIA devices are generally classified by the number of frequencies and the number of electrodes or contact points utilized for analysis (Moon). Prior to the 1990s, most BIA devices only operated at a single frequency of 50 kHz using two to four electrodes, and empirical equations were used to predict body composition (Pateyjohns et al.). RJL Systems introduced one of the first single-frequency BIA machines in 1979. Their machine utilized two to four adhesive electrodes placed ipsilaterally on a hand and a foot to allow a small electrical current to be transmitted through an individual's body (Lukaski). This method estimates approximately half of the body and assumes the other half of the body is similar in composition to estimate total body composition. Since the 1990s, advances in BIA technology have produced devices such as handheld devices and standing devices like scales, and even newer devices equipped with direct segmental multi-frequency BIA (DSM-BIA) to estimate total body composition.

Handheld devices, such as the Omron, provide a hand-to-hand assessment through hand-grip metal contacts, and utilize the upper body results to estimate the composition from the chest down to the feet. Scales equipped with BIA technology, such as the Tanita or home scales, provide a leg-to-leg assessment through foot-pad metal contacts. These devices use the leg results to estimate the composition of the upper half of the body. These older and less expensive devices tend to have four points of contact, so assumptions must be made regarding the parts of the body not measured, and thus introduces room for error in assessing body composition. These devices also use only a single frequency to calculate impedance. Single-frequency BIA devices are limited in their ability to distinguish the proportion and distribution of TBW into extracellular water (ECW) and intracellular water (ICW) (Research et al.). While this methodology may be used for healthy, euhydrated populations with normal electrolyte balance, obese populations tend to carry more water in lean body mass, which may produce invalid body composition results (Pateyjohns et al.). Lower frequencies cannot penetrate cell membranes and can only be used to estimate ECW, while higher frequency machines can penetrate cell membranes and can also predict ICW (Moon). BIA methods that use higher frequencies are preferred for predicting lean body mass because muscle tissues generally contain a large portion of ICW (Moon).

Newer eight-point electrode systems have become widely available in recent years. BIA devices that use DSM-BIA, such as the InBody or SECA brands, utilize eight points of contact to assess total body composition through both hand and foot metal contacts. This allows for analysis at five different segments of the body; both arms and legs, and the torso. The InBody specifically uses a mixture of a total of six low and high frequencies to determine both ECW and ICW. This in conjunction with the five-segment analysis allows body composition to be determined without the use of population-specific algorithms (Pateyjohns et al.).

The websites of the BIA devices used in this study were reviewed for manufacturer-proposed validity and reliability. Tanita's owner's manual discusses factors giving error in measurement for their device, and if their instructions are followed, they state "very stable measured values can be obtained" from their device. Included in the Tanita owner's manual is a study demonstrating the degree of inter-day changes in impedance during dehydration compared to a "normal daily routine." The noted study concludes, "no significant inter-day change was measured in body weight, impedance between the feet, or body fat percentage during the normal daily routine", although no reference to this study is cited. The manufacturers of the InBody 770 state their device is capable of detecting sensitive changes in body composition "primarily through impedance measurement which has proven an unusually high level of precision." They also cite six studies on their website that support the validity of their devices. Both Omron's and Greater Goods' owner's manuals and websites do not market the reliability of their device. While limited information was provided on the proposed validity and reliability of the devices, most manufacturers stated the importance of a standardized protocol to ensure reliable measures when using their devices.

With a vast selection of BIA devices available, it is no question as to why there is consumer confusion on which device is most accurate and the meaning behind differing results for the same machine. Comparison of one machine to a reference method will help identify the accuracy or validity of a machine, while comparison of data produced by one machine across multiple encounters will help identify the precision or reliability of a machine. While companies will typically provide estimates of validity and reliability in advertising materials, it is important to look to the unbiased literature for replication of company-driven numbers. This study will focus on reliability studies of particular devices that are available in the peer-reviewed literature.

Reliability Studies

The earliest published studies regarding the reliability of BIA utilized RJL Systems single-frequency BIA devices. (Fornetti et al.; Jackson et al.) (1988) examined the reliability of the BIA-103B, a four-terminal, single-frequency impedance analyzer, on 44 women and 24 men. Each participant's body composition was assessed four times by two testers on two different days within one week of each other. The standard errors for the two measurements ranged from 4.6-6.4%, and the reliability coefficients for both males and females were high (R_{xx} = 0.957 and 0.967, respectively). The authors concluded that participant-by-day error accounted for >60%

of BIA error variance, demonstrating that the major source of BIA measurement error was due to changes within participants rather than tester error.

Fornetti et al. (1999) studied the reliability of RJL Systems' BIA-101A, a two-terminal, single-frequency impedance analyzer, on 132 female athletes age 18-27 years old. Each participant's body composition was assessed two times, although the time between trials is not noted in the study. Reliability coefficients were high (R_{xx} = 0.987–0.997) for all measures when analyzed for both repeat and single trials. Authors explained, "it is important to note that the high reliability coefficients obtained in this study were likely a function of the short interval between trials and the close attention to manufacturers' instructions regarding measurement techniques paid by the investigator."

Lastly, Erselcan et al. (2000) assessed the reliability of the Bodystat 1500, a two-terminal, single-frequency device similar to the RJL Systems. Of the 37 participants in the study, four participants' body composition was assessed two times within a two-weeks period. The standard errors for the two measurements ranged from 6.2-7.8%.

The Tanita and Omron are common BIA machines. Mooney et al. (2011) assessed the reliability of three BIA devices, the Omron HBF-306CN, Tanita 300A, and Tanita 521, on 79 participants age 12-17 years old (47 boys, 32 girls). Each participant's body composition was assessed twice on the same day, and re-tested 2-7 days later at the same time of day as the first assessment to determine within- and between-day reliability of the BIA devices. The within-day repeated measurements differed by 0.89, 0.61, and 0.39 standard deviations for the Tanita 521, Omron, and Tanita 300A, respectively. The between-day repeated measurements differed by

0.81, 1.22, and 1.21 standard deviations for the Tanita 521, Omron, and Tanita 300A, respectively. The study concluded that each device was reliable within and between days.

The Tanita BC418-MA is an eight-contact electrode system capable of estimating segmental body composition, much like the InBody 770 used in the present study. Kelly and Metcalfe (2012) assessed the within-day reliability of the Tanita BC418-MA in 24 males age 26-50 years old and 28 females age 34-56 years old. Participants' body composition was initially measured then retested 15 minutes later. Participants were to remain standing in between the measurements. A good level of reliability was demonstrated with a test-retest coefficient of variation of 1.4%. There was no significant difference between mean values, 23.38% body fat for trial 1 and 23.37% body fat for trial 2.

Determining the reliability of machines across a typical day under different circumstances has been studied using the Omron. Wheeler et al. (2013) assessed the within-day reliability of the Omron HBF-306CN in 91 participants, age 18-39 and 55-75 years old, at three points throughout the day; immediately after waking and voiding their bladder, after eating lunch, and prior to bed. Researchers found significant differences ($p<0.001$) in body fat percentages between the three measures, although estimates of body fat percentage varied by less than 1%.

The InBody 230 is an eight-electrode unit that uses two frequencies. Hurst et al. (2016) studied the reliability of the InBody 230, as well as the BodPod and iDXA, in 166 participants age 19-71 years old with BMIs ranging from 19-38 kg/m^2. Body composition was assessed on all three devices on two occasions that were no more than five days apart. The study concluded that the InBody 230's repeat measurements differed by less than 0.2% ($P=0.09$). Each participant's body composition was tested at approximately the same time of day for each visit, and participants were asked to refrain from eating, drinking or exercising for at least two hours before their appointments. For the InBody test, participants were also asked to wear minimal, tight-fitting clothing such as a swimsuit. The researchers attributed the minute difference in body fat percentage between the two encounters to their strict protocol.

Although research is scarce, the minute variation between repeat measures found in the most recent literature above may suggest these newer BIA devices, such as the InBody, Tanita, and Omron, provide dependable data more so than dated BIA devices like the RJL and Bodystat. However, variability in methodology and time intervals between tests, the lack of research on the most updated BIA models, and the increasing popularity of multifrequency BIA devices, indicates the necessity for assessing their consistency in estimating body composition on multiple encounters to add to the literature.

Materials and Methods

This protocol was designed as the reliability arm of a larger validity study (IRB#2018H0326). Participants for this reliability study were recruited from a convenience sample of Sports Nutrition Laboratory personnel. By design, the study sought to measure participants' body composition day-to-day on differing machines under normal use circumstances. Normal use in this context means at normal hydration, slightly various clothing, and similar times of day.

A total of five encounters occurred over a two-week period for each participant. At the initial visit, the participant recorded height and weight. For each consecutive visit, only weight was recorded for use with the initial height. Prior to beginning the BIA assessments, urine specific gravity (USG) was documented using a urine refractometer for the statistical purpose of controlling for hydration status. Body composition was assessed and recorded for the four selected BIA devices at each encounter.

Selected BIA Devices			
InBody 770	Tanita Body Composition Analyzer SC-331	Omron HBF-306CN	Greater Goods Digital Home Scale

The InBody 770 is a multi-frequency, standing BIA device capable of estimating fat mass, fat-free mass, total body water, segmental lean mass, and segmental body water analysis. The machine requires the following data input: participant ID, age, gender, and height in inches. The machine measures the user's body weight. After data input, the user is instructed to first place their feet on top of the foot contact pads, then lift and grip the two hand analyzers, place their arms out to the side of the body (making sure the arms do not touch the sides of the body), and lastly, to remain still and quiet during the approximate one-minute scan. Results are stored in the machine and can be downloaded digitally if desired.

The Tanita Body Composition Analyzer SC-331 is single-frequency, standing BIA device capable of estimating fat mass, fat-free mass, body water percentage, and bone mass. The machine requires the following data input: clothing weight, gender, height in inches, age, and standard vs. athletic body type. Clothing weight was minimal and thus entered as 0# to standardize the protocol. It varied whether participants selected the "standard" or "athletic" body type option. After data input, the user steps onto the scale with four foot contacts, and the machine then measures the user's body weight. The Tanita assesses the lower body using a non-invasive electrical current, and uses the obtained information to estimate full body composition. The results are printed onto a small strip of paper immediately after the approximate 20 second assessment.

The Omron HBF-306CN is a single-frequency, handheld BIA device capable of estimating body fat percentage. The machine requires the following data input: height in inches, weight in pounds, age, gender, and athletic vs. standard body type. After data input, the user grips the two handles with four metal contacts and straightens their arms out in front of them, making sure that the arms do not touch the sides of their body.

The Greater Goods Digital Home Scale is designed for individual home use. The scale is equipped with single-frequency BIA technology, and only requires the user to input their age, gender, and height in inches. After data input, the user steps onto the scale with four foot contacts, and the machine then measures the user's body weight. The device assesses the lower body using a non-invasive electrical current, and uses the obtained information to estimate full body composition. The machine calculates the user's BMI, body fat percentage, muscle mass, body water, and bone density.

Statistical Methods: All data were downloaded or hand-entered into an Excel spreadsheet then double checked for accuracy of entry. Data were imported into SAS version 9.4 for statistical analysis and descriptive data were generated. The repeatability and variability of estimations for body fat percentage were analyzed across devices for five time points using the GLIMMIX procedure. The utilization of generalized linear mixed modeling allowed for underlying normally distributed random effects. Mixed modeling is also less concerned with the equality of variances or underlying assumptions. The procedure also allows the user to control for time variant covariates such as weight and USG. Apriori statistical significance was set at $P<0.05$.

Results

A total of eight participants volunteered to be in the study, of which seven were female and one was male. Participant characteristics are presented in Table 1. The mean age for females was 27.7 years old and the male participant was 30 years old. The mean weight for females was 128.6 pounds and the male participant weighed 195.6 pounds. The mean height for females was 63.1 inches and the male participant was 73.4 inches tall.

	Gender	Mean	SD	Range
Age (years)	Female	27.7	4.56	22-55
	Male	30	0	
Weight (lbs)	Female	128.6	7.90	105.4-156.6
	Male	195.6	0	
Height (in)	Female	63.1	1.16	59.3-68.2
	Male	73.4	0	
Body Fat* (%)	Female	23.7	2.26	17.2-32.1
	Male	21.6	0	
USG	Female	1.014	0.0073	1.003-1.027
	Male	1.022	0.0087	1.008-1.033
* Body fat as determined by the InBody 770.				

Table 1: Descriptive Data of Participants (n=8)

The GLIMMIX procedure in SAS version 9.4 was used to analyze the reliability across encounters by BIA method. Body fat percentage was the dependent variable and the fixed factors were methods (4 levels) and repeated measures (5 days). Body fat percentages were compared between the BIA methods and across days. Table 2 outlines the raw averages for each method across the 5 days, and Table 3 presents the Type III Sums of Squares of the model.

The model demonstrated significant differences between methods, and these are contained in the solutions for fixed effects (Table 4). The Tanita and InBody produced significantly different body fat percentages (p=0.0123), while no significant differences in body fat percentages were observed between the other BIA methods (P>0.05). There were no significant differences in body fat percentage for each method across the five encounters (P>0.05).

Encounter	1	2	3	4	5	Mean $\pm$ SD
Tanita	21.28	20.70	19.99	20.66	20.38	20.6 $\pm$ 7.69
Omron	21.55	22.25	21.44	22.05	21.91	21.8 $\pm$ 4.61
Digital Home	20.18	19.94	20.58	20.79	21.40	20.6 $\pm$ 4.28
InBody	23.40	24.31	24.20	24.29	23.84	24.0 $\pm$ 5.15

Table 2: Mean Body Fat Percentage for Each Method Across 5 Encounters

Type III Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Day	4	133	0.13	0.9713
Method	3	133	13.99	<.0001
Method*Day	12	133	0.25	0.9951

Table 3: GLIMMIX Type III Tests of Fixed effects for model containing day, method, and the interaction

Solutions for Fixed Effects							
Effect	**Method**	**Day**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
Intercept			20.3750	2.0829	7	9.78	<.0001
Day		1	0.9000	1.3639	133	0.66	0.5105
Day		2	0.3250	1.3639	133	0.24	0.8120
Day		3	-0.3875	1.3639	133	-0.28	0.7768
Day		4	0.2875	1.3639	133	0.21	0.8334
Day		5	0	.	.	.	.
Method	Digital		1.0250	1.3639	133	0.75	0.4537
Method	InBody		3.4625	1.3639	133	2.54	0.0123
Method	Omron		1.5375	1.3639	133	1.13	0.2617
Method	Tanita		0	.	.	.	.

Table 4: Solutions of Fixed Effects for model containing day, method, and the interaction

There were no significant differences for the influence of day or the interaction of method by day for the model. This means that the body fat values estimated across the five days for each machine were stable and statistically similar. The largest difference in mean body fat percentage between the five encounters was obtained from the Greater Goods Digital Home Body Scale with a 1.5% variation, followed by the Tanita with a 1.25% variation, and the InBody with a 0.9% variation. The Omron had the smallest variation in means, 0.8%, between the five encounters. While these numbers look reasonable it is important to understand the underlying data.

While it is not typical to examine individual data, the standard deviations for these devices are wide and the individual results may be surprising. Table 5 illustrates the difference in body fat percentage per device across the five encounters for one participant; the difference in body fat percentage for the four devices ranged from 2.2-9.4% for this participant. Given the study only included 8 participants, plots were constructed for each to understand the range of variability. Figure 1 illustrates each participant's variation in body fat percentage per device across the five encounters.

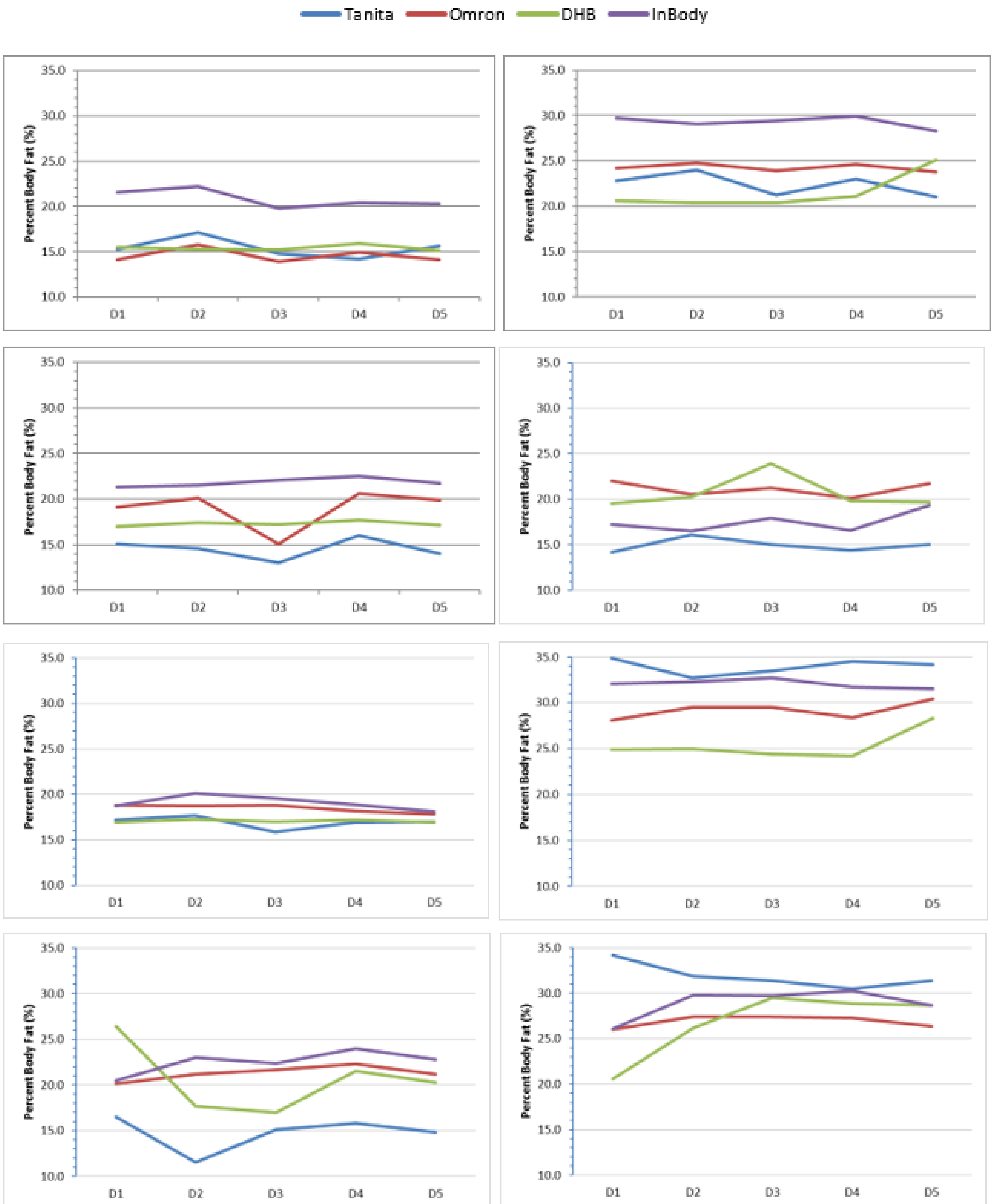

Figure 1: Variation in Body Fat Percentage for Each Participant Across Four BIA Devices

	Body Fat % per Device (%)			
Encounter	Tanita	Omron	Digital	InBody
1	16.5	20.1	26.4	20.5
2	11.5	21.2	17.7	23.0
3	15.1	21.7	17.0	22.4
4	15.8	22.3	21.5	24.0
5	14.8	21.2	20.3	22.8
Range	11.5-16.5 (5%)	20.1-22.3 (2.2%)	17.0-26.4 (9.4%)	20.5-24.0 (3.5%)
Mean $\pm$ SD	14.74 $\pm$ 1.93	21.3 $\pm$ 0.809	20.58 $\pm$ 3.74	22.54 $\pm$ 1.28

Table 5: Example of variation in body fat percentage for one randomly selected participant

The study also analyzed the role of hydration by including USG in the model with method and day as fixed variables, as well as all possible interactions. The Type III Sums of Squares are provided in Table 6. To no surprise, USG was not predictive of body fat, but there was a trend for the interaction between USG and method (p=0.0531). In this same model, methods were also dampened to a similar trend (p=0.0546). It is possible that this indicates that the interaction of USG with method explains some of the variance between the methods.

Type III Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Day	4	113	0.25	0.9090
Method	3	113	2.61	0.0546
Method*Day	12	113	1.49	0.1384
USG	1	113	0.05	0.8207
USG*Day	4	113	0.25	0.9090
USG*Method	3	113	2.64	0.0531
USG*Method*Day	12	113	1.49	0.1391

Table 6: GLIMMIX Type III Tests of Fixed Effects for model containing day, method, USG, and all possible interactions

The InBody, Tanita, and Home Body all weigh the person as part of the body fat estimation. During measurements, it was noticeable that these weights did not match well so differences in methods and days were modelled with weight as an additional fixed factor as well as all interactions. The results are delineated in Table 7. Again, there was a significant interaction between method and weight (p=0.0002) potentially indicating the potential influence of weight as taken by the machine on the predicted body fat of that method. Method also remained significant in this model.

Type III Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Day	4	113	0.06	0.9935
Method	3	113	6.65	0.0004
Method*Day	12	113	0.10	0.9999
Weight	1	113	0.31	0.5799
Weight*Day	4	113	0.06	0.9938
Weight*Method	3	113	7.04	0.0002
Weight*Method*Day	12	113	0.11	0.9999

Table 7: GLIMMIX Type III Tests of Fixed Effects for model containing day, method, weight, and all possible interactions

Both the weight and USG models also demonstrated a lack of significance for day (repeated measures) and no significance for interaction with day or the three-way interactions. The measures for each device across did not appear significantly different according to the GLIMMIX modeling procedure.

Discussion

The present study aimed to evaluate the reliability of four commonly utilized BIA devices in assessing body fat percentage across a total of five encounters. The utilization of generalized linear mixed modeling allows for fixed and random effects, thus is more forgiving for the underlying assumptions for the analysis.

Although body fat percentages between days for each device were not statistically significant, variance among means were present. Talma et al. conducted a systematic review of the reliability of BIA and found considerable variability in methodology and time intervals between tests, with encounters ranging from 90 seconds to five weeks apart. Despite these issues, absolute differences in body fat percentage were relatively low, ranging between 0.9% and 1.61% (Talma et al.). Other studies found variation in mean body fat percentages for individual within-day BIA measurements ranging from 0.3% to 2.8%, and daily or weekly variability ranging from 0.9% to 3.6%, respectively (“Bioelectrical Impedance Analysis (BIA)”). The variability for all devices for this study ranged from 0.8-1.5% so is in reasonable agreement with the literature. Variation between repeated measurements may be common for BIA devices since several factors can affect body composition results.

Hydration status is clearly important when utilizing BIA technology, as the method is reliant on estimations of total body water to estimate fat-free mass. Because of this, USG was recorded at the beginning on each encounter to allow for statistical control for (analysis of) hydration. Participants’ USGs were to be in normal range between 1.008 and 1.020 to ensure proper hydration. The range for our participants was 1.003 to 1.033 with an average of 1.015 indicating that our cohort was fairly well hydrated on most days. Saunders found that BIA was not a suitable method of body composition assessment in athletes with abnormal hydration status from endurance training. Relatively small changes in fluid balance may be interpreted as change in body fat percentage, and although no significant differences were found between body fat percentage values and hydration levels (Saunders) the premise that BIA methodology is dependent on estimations of total body water may explain some of the variation between individual's body fat percentage per encounter. The difference in hydration status during menses may also significantly alter impedance (Gleichauf), and thus should be a consideration when utilizing BIA devices to assess females. Although the point in individuals' menstrual cycles were not assessed in this study, menses' effect on total body water may be important to note since six of the eight study participants were menarcheal females.

The lack of a standardized protocol when operating BIA devices can result in unreliable values. Factors such as hydration status, temperature, eating, physical activity, fluid equilibrium, and menstrual status play a role in obtaining valid and reliable body composition measures. Thus, performing these tests under the same conditions may increase the reliability of these devices. Wheeler et al. found significant differences between three measures of body fat percentage performed over the course of a day. Participants were tested immediately after waking and voiding their bladder, after eating lunch, and prior to bed (Wheeler et al.). This study, along with others in the literature, exemplify the need for devising and following a protocol for performing an initial body composition test, as well as subsequent tests to monitor changes.

Limitations

Human error can also affect the results provided by these BIA devices. The Omron requires manual entry of gender, height, age, and weight, while the Digital Home Body, Tanita, and InBody all require the manual entry of gender, height, and age. Error is introduced when values are incorrectly entered into a device or when values like height are estimated. Participants in the current study entered their personal data into the devices, so entry error is unknown but nonetheless possible.

Lastly, the small number of participants involved in this study is a significant limitation, as well as the lack of diversity among the participants (i.e. majority were younger females within low to normal body fat ranges). More participants would allow for a wider study pool and further conclusions to be made on the reliability of BIA devices in other populations (i.e. under-/over-/obese individuals, various age groups, males, etc.). While our study concludes there is no difference, it lacks power. Using the mean and pooled standard deviation from the two most divergent methods of the Tanita and InBody, the power calculated to be 18% where a power of at least 80% is desirable. Conversely, using the same means and standard deviations, the study would have needed to matriculate 56 participants to see a difference between the Tanita and InBody, and 77 people to see a difference between the Omron and InBody.

Future research can improve the results of this study by first utilizing a strict protocol which considers hydration status, fueling and exercise guidelines, clothing, and fluid equilibrium to aid in obtaining reliable measures. Secondly, recruiting a larger, more diverse sample size would allow for greater statistical power. Lastly, while these devices are relatively simple and easy to use, having one lab member obtain all measurements on the same machine would decrease potential variations in machine operation.

Conclusion

To conclude, the InBody 770, Tanita Body Composition Analyzer SC-331S, Omron HBF-306CN, and Greater Goods Digital Home Scale may be reliable methods of tracking body composition over time. Professionals, as well as lay users, must be aware of the potential variability between body composition measures per assessment, as well as the factors that can affect body composition results when using these BIA devices. The variation in body fat percentage between the devices encourages professionals and the general public to consistently use one device rather than multiple devices to collect body composition data.

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